MATH AND SCIENCE @ WORK

AP* BIOLOGY Student Edition

RESPIRATION IN SPACE FLIGHT

Background

Since its conception in 1981, NASA has used the space shuttle for human transport, the construction of the International Space Station (ISS), and to research the effects of space on the human body. One of the keys to the success of the Space Shuttle Program is the Space Shuttle Mission Control Center (MCC). The Space Shuttle MCC at NASA Johnson Space Center uses some of the most sophisticated technology and communication equipment in the world to monitor and control the space shuttle flights.

Within the Space Shuttle MCC, teams of highly qualified engineers, scientists, doctors, and technicians, known as flight controllers, monitor the systems and activities aboard the space shuttle. They work together as a powerful team, spending many hours performing critical simulations as they prepare to support preflight, ascent, flight, and reentry of the space shuttle and the crew. The flight controllers provide the knowledge and expertise needed to support normal operations and any unexpected events.

One of the flight control positions in the Space Shuttle MCC is the Emergency, Environmental, and Consumables Manager (EECOM). The EECOM flight controller monitors and regulates the cabin atmosphere which includes gas concentrations and pressures within the space shuttle cabin. Maintaining these parameters ensures a habitable cabin atmosphere and temperature on board the space shuttle much like the atmosphere here on Earth. These conditions allow the crew to work in a “shirt sleeve” environment while in the cabin (i.e. the crew can wear normal clothing rather than the protective clothing that is necessary outside of the cabin area).

Figure 1: Astronauts Thomas D. Jones, mission specialist, and Mark L. Polansky, pilot, change out lithium hydroxide canisters on the mid deck of the Earth-orbiting Space Shuttle Atlantis

Figure 2: Astronaut Sandra Magnus uses a computer on the middeck of Space Shuttle Endeavour during flight activities.

Air is circulated in the space shuttle cabin using fans that force the air through cabin air loops where the air is conditioned. Conditioning the air involves a series of processes that remove dust particles, heat, humidity, and carbon dioxide (CO_2). The absorption method used to remove carbon dioxide from the air involves a chemical reaction using lithium hydroxide (LiOH) as the sorbent. Lithium hydroxide is an attractive choice for space flight because of its high absorption capacity for carbon dioxide and the small amount of heat produced in the reaction. Lithium hydroxide canisters are located in mid deck of the space shuttle and their replacement is a daily activity during space shuttle flights. There is a potential for some toxicity within the space shuttle cabin due to lithium hydroxide dust that could be ingested by the crew. Before a space shuttle mission, EECOM flight controllers and crewmembers receive training that ensures correct precautions and procedures are followed while replacing the lithium hydroxide canisters.

Problem

Figure 3 is a graph that depicts the concentrations of CO_2 in the space shuttle over a 4 day period. During each 24 hour period, an estimated 3.5 canisters of LiOH are required to remove the CO_2 produced by the crew (this number is based on a crew of 7 people). Each peak and valley in the graph represents a LiOH changeout. The peak represents the installation of the canister(s) and the valley represents the canister(s) being saturated with CO_2. Each LiOH changeout could include either one or two canisters being replaced. The larger peaks shown in Figure 3 represent the replacement of two canisters while the smaller peaks represent only one canister replacement. If a high level of metabolic oxygen consumption is predicted, a LiOH canister would be installed prior to the high metabolic rates in order to preclude reaching a high level of partial pressure of CO_2. In the graph, periods of high metabolic consumption are represented by the slope of increase in CO_2. Before a flight, EECOM flight controllers use data collected from previous missions to predict the number of LiOH canisters that will be needed and the time intervals of their installation to ensure the health and safety of the crew. If actual data shows higher or lower than predicted, the EECOM flight controller will make a recommendation of adding or removing a canister changeout.

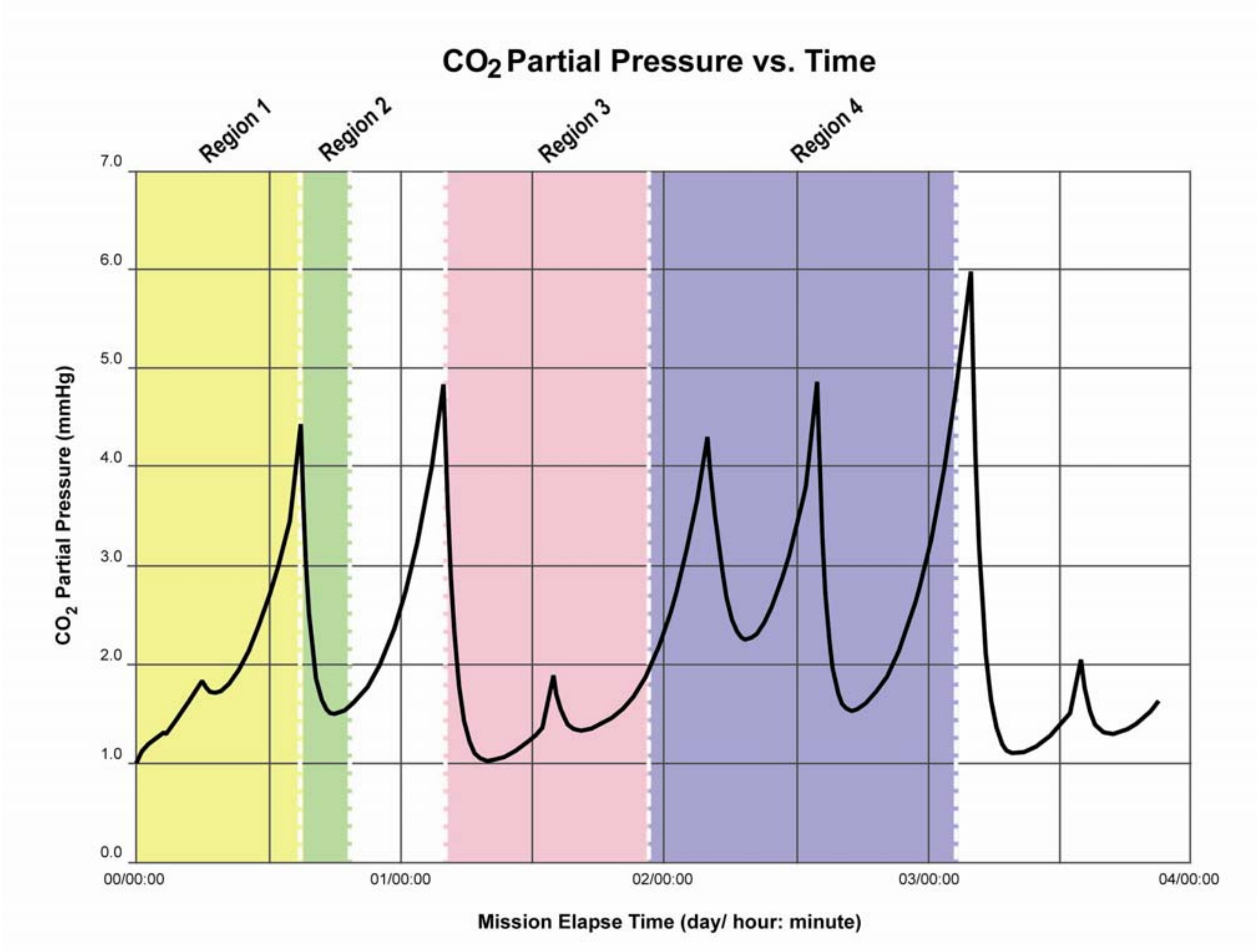

Figure 3: Partial pressures of CO_2 in the space shuttle cabin during a four day period. Note that this is a replicated graph using data from previous space shuttle missions.

A. Name two methods for measuring cellular respiration. Which method is Figure 3 depicting?

B. Using Figure 3, describe the metabolic events represented in each region. Explain your answer in terms of cellular respiratory function, physiological respiratory function and activity, and environmental gas balance and pressures.

   I. Region 1

   II. Region 2

   III. Region 3

   IV. Region 4

C. Suppose convection currents (air flow due to temperature and pressure changes) were not forced using fans as described in the provided background. List the symptoms (with causes) that the crew members might exhibit as a result.

D. Suppose in an emergency situation there is an unexpected drop in oxygen (O_2) partial pressure detected by the EECOM flight controller. Crewmembers begin to exhibit symptoms similar to those of high altitude mountain climbers that could be from one or a combination of gas factors. Identify how the gas levels cause the physiological symptoms in two of the four systems: circulatory, respiratory, nervous, and muscular.